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UNFERMENTED APPLE JUICE.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., July 7, 1908.

SIR: I present herewith a manuscript prepared by Mr. H. C. Gore on the preservation of fresh fruit juices, apple juice being used in these experiments. This is an industry of increasing importance in the United States, and it is only necessary to its still more rapid development that some unobjectionable method for the preservation of such juices be practiced. There is a continuing objection to the use of chemical preservatives in products of this kind, and the work here presented shows that these juices may be perfectly preserved, either in small or in large quantities and with a much better flavor, by means of sterilization alone. The work is of a practical character, having been conducted on a scale which can easily be extended to commercial proportions.

Mr. W. A. Taylor, pomologist in charge of field investigations, Bureau of Plant Industry, cooperated in the work by advising as to the selection of the varieties of apples employed, by serving on the committee of experts who judged of the quality of the completed product, and in other ways, giving valuable advice whenever the pomological features of the investigation were under consideration.

I recommend that this report be published as Bulletin No. 118 of the Bureau of Chemistry.

Respectfully,

H. W. WILEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction.....	5
Sterilization of apple juice.....	5
In wood.....	5
Experiments with barrels.....	6
Experiments with kegs.....	7
Organoleptic tests of the juice from kegs.....	10
In cans.....	10
Conditions of processing.....	10
Quality of juice obtained from different varieties of apples.....	11
Organoleptic tests of canned juice.....	12
Action of the juice on the tin of the can.....	13
Spoilage.....	14
In glass.....	15
Clarification tests.....	15
Methods employed.....	15
Results obtained.....	16
Carbonating.....	17
Methods employed.....	17
Use of carbon dioxid to prevent mold.....	18
Effect of benzoate of soda as a preservative.....	19
Summary.....	22

ILLUSTRATIONS.

	Page.
FIG. 1. Pasteurizer for apple juice.....	6
2. Small pasteurizer for sterilizing apple juice in kegs	7
3. Apparatus for paraffining kegs.....	8
4. Three views of wooden bung showing cotton plug and substitution of wooden skewer.....	9

UNFERMENTED APPLE JUICE.

INTRODUCTION.

The process of sterilizing, so extensively employed with other products, is not widely practiced with apple juice, probably because information is lacking as to methods of handling and the character of the product which may be obtained.

In an extensive treatise on cider making by a British investigator, F. J. Lloyd,^a sterilization is not mentioned as a practical process. Warcollier^b states that no method of sterilizing the fresh must has yet been commercially used in France. A report from the American consul at Munich gives a method of sterilizing employed there. It applies, however, only to bottled apple juice. In America methods have been developed for the preparation of bottled apple juice, but they have received no general application.

With a view to gaining information as to methods of sterilizing apple juice, experiments were conducted during the season of 1906^c in Nebraska and continued during 1907 at Washington, D. C. Apple juice is found to be a product which it is easy to sterilize, while conserving to a large extent the delicious flavor of freshly expressed juice. The process is inexpensive and capable of application on a small or large scale. If desired, the product may be carbonated before use, and when so treated closely resembles apple cider in which the natural fermentation is just beginning.

The term "sterilization" as used herein indicates that the fruit juices treated as described do not develop any bacterial or fungous growths within the period usually elapsing before their consumption. The temperatures employed, however, are those commonly used in the process termed "pasteurization."

The various phases of the investigation will be discussed, experiments having been made with wooden, tin, and glass containers, with different methods of clarifying and carbonating, and with the use of preservatives.

STERILIZATION OF APPLE JUICE.

IN WOOD.

These experiments were made to develop a method for sterilizing apple juice in wooden containers so that it might be marketed with-

^a Report on the Results of an Investigation into Cider Making, etc., 1893-1902. London, 1903.

^b Les méthodes scientifiques dans l'industrie du cidre. Rev. gén. sci. pures et appliquées, 1907, 18:778.

^c Yearbook of the U. S. Department of Agriculture, 1906, p. 239.

out the use of chemical preservatives, such as benzoate of soda, which is commonly used at present. Aside from hygienic reasons, experiments (see p. 19) have shown that the use of benzoate of soda is far from being a satisfactory means of preserving apple juice. The objections urged against sterilizing are (1) that a "cooked" taste is added to the juice, greatly injuring the flavor, and (2) that it is impracticable to hold the juice sterile for more than a limited period. These objections have been met. The investigations here reported demonstrate that only a slight cooked taste is produced by the heat treatment required and that it is a simple matter to protect the juice from inoculation after sterilizing.

EXPERIMENTS WITH BARRELS.

In the experiments of 1906^a on sterilizing in barrels, it was found that they could be successfully used as containers when it was desired to keep the juice sweet for a few weeks.

In one experiment two 50-gallon barrels were thoroughly cleaned, well steamed, and filled with the juice heated to between 149° and 158° F. (65° and 70° C.). In sealing a cask which is full of hot liquid, air should be allowed to enter during cooling to destroy the vacuum caused by the contraction of the liquid. Unless this is done, a severe strain is put on the cask, greatly increasing the danger of contamination. In this experiment, instead of at first driving in bungs to close the barrels, clean cotton plugs were used. When the casks and contents were cool, the

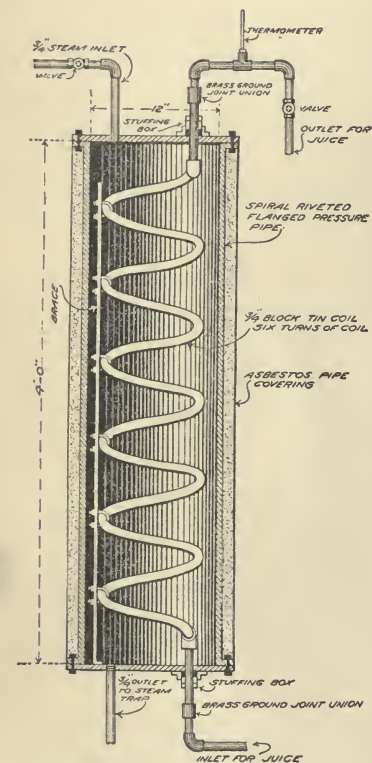


FIG. 1.—Pasteurizer for apple juice.

plugs were removed and wooden bungs which had been sterilized by soaking in alcohol were quickly inserted. The juice kept for ten days without showing fermentation.

In this experiment the pasteurizer shown in fig. 1 was employed and proved to be a very useful machine, capable of heating the juice with perfect control of temperature at any desired rate up to several hundred gallons per hour. This pasteurizer was built for about \$50.

^a Loc. cit.

EXPERIMENTS WITH KEGS.

Further experiments on sterilizing in wood were made during the season of 1907-8, and the results show that wooden containers can be successfully employed for fairly long periods of time. In these experiments, 10-gallon kegs made of No. 1 white-oak stock, costing \$1.05

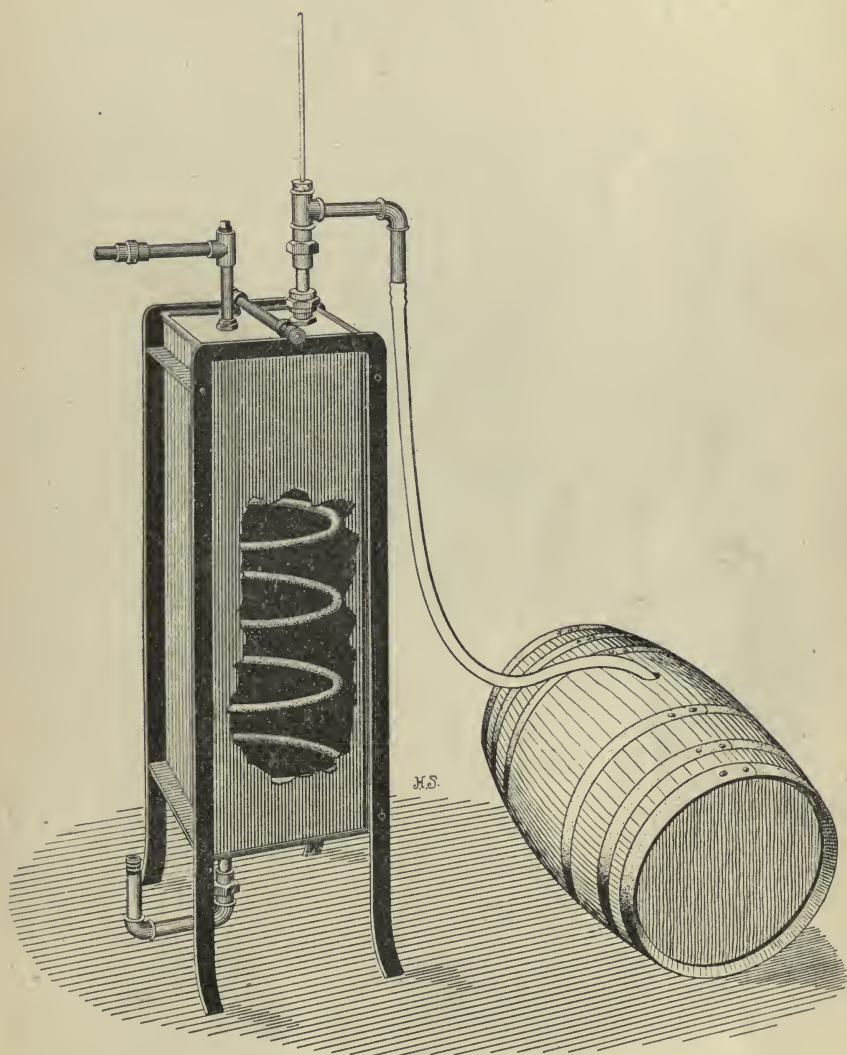


FIG. 2.—Small pasteurizer for sterilizing apple juice in kegs.

each, were used. A pasteurizer of smaller size was employed, similar to the one shown in fig. 1, but built of lighter material and costing about \$12 (fig. 2). The results were satisfactory and demonstrate that this model will be found useful in work conducted on a small scale.

The kegs were prepared for use as follows: They were paraffined on the outside by dipping in a bath of melted paraffin which was heated to about 120°C. (248°F.) by means of a steam coil. The arrangement is shown in fig. 3. Steam was run into the keg for about three minutes, when it was allowed to cool somewhat, and sulphured by lowering into each keg a small crucible filled with burning sulphur. The kegs were allowed to stand closed overnight, and in the morning just before filling they were steamed out for three minutes and well rinsed, removing practically all of the sulphur. It was found that a longer period of steaming melted the paraffin on the outside of the kegs.

The juice was heated by running through the pasteurizer at from 65° to 70°C. and was delivered directly into the kegs. As each was filled, it was closed in the following way: A wooden bung which had been paraffined and then dipped in alcohol was placed in the bunghole. The quarter-inch hole in the center of the bung was stuffed with cotton and the bung was driven into the keg (fig. 4*a*).

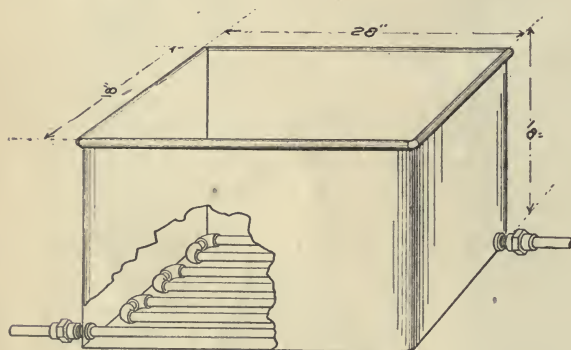


FIG. 3.—Apparatus for paraffining kegs.

was removed and another plug immediately inserted and saturated with alcohol. The cotton is stuffed into the bung before the bung is inserted in order to prevent the entrance of organisms while it is being driven in, and is replaced by a fresh plug of cotton afterwards, because

it usually becomes saturated with juice during the driving. This plug of cotton, sterilized by alcohol, prevents access of organisms during cooling, the air sucked in on account of the contraction of the juice on cooling being filtered through the cotton. When the juice had cooled the cotton plug was cut off at the surface of the bung, the portion of the plug remaining was wet again with alcohol, and a wooden skewer, fitting the hole in the bung closely, was sterilized by soaking in melted paraffin, then in alcohol, and driven into the hole, forcing the cotton plug out. In this way the cotton plug was replaced by a sterilized wooden plug without any chance for the entrance of organisms. The skewer was then sawed off even with the surface of the bung and smoothed over by a little melted paraffin (fig. 4, *b* and *c*).

Forty 10-gallon kegs were filled in this way, and of these 22 were kept unopened for more than six months, the juice in the remaining kegs being used for other purposes. The juice was prepared from

apples grown in the vicinity of Washington, being mostly of the Grimes (syn. *Grimes Golden*) variety, with some Winesaps, and while the fruit was sound and clean the juice was not of high quality, lacking in acidity and fruitiness. In no case, however, has the juice failed to keep well. The kegs were kept for the first two months in a warm cellar at about 20° C. Twenty-four were then subjected to a shipping test. Four lots of six kegs each were shipped by freight to Charlottesville, Va., and were held for periods of from two to four weeks in the cellar of W. B. Alwood, in charge of the enological investigations of the Bureau of Chemistry at that point, and then were returned to Washington. In no case was there any loss due to fermentation, although several kegs were injured in transit.

The first shipment left Washington on January 30, 1908, arriving in Charlottesville on February 3 in good condition. One keg of this lot was opened by W. B. Alwood and the following notes were made: "February 12, 1908. * * * I opened one keg of the first shipment of cider to-day and found it very good. Color yellowish straw, not translucent, but not muddy. Flavor excellent, barring slight cooked taste. Per-

fectly sweet and sound. Sp. gr. 1.053. I was able to take out with a siphon 35 quarts of fairly bright cider; 5 quarts were too muddy for use without sedimentation or filtering." On February 15 the remaining casks of this lot were returned to the Bureau of Chemistry at Washington, arriving in good condition. One of the kegs of the second shipment was leaking very slowly when received at Charlottesville, but the contents were found to be perfectly sound. The third shipment was received in good condition; but of the fourth shipment one keg was leaking, owing to a broken stave. Mr. Alwood calls attention to the fact that these kegs were too frail for the rough usage given freight, as the handlers drop them flat and thus spring the staves.

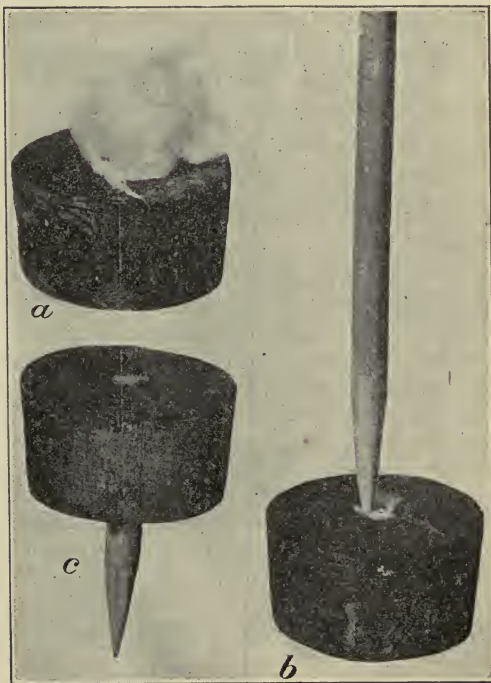


FIG. 4.—Wooden bung for cider barrels: a, Showing cotton plug. b, Skewer about to be driven in to displace cotton. c, Skewer in final position.

All of the shipments from Charlottesville were received at Washington in good condition and have kept well subsequently.

ORGANOLEPTIC TESTS OF THE JUICE FROM KEGS.

On May 29 a keg was opened, the contents cooled to about 15° C. (59° F.), and a test made by a committee of three experts, H. W. Wiley, William A. Taylor, and J. A. Le Clerc, with a view to securing data as to the value of the product as a beverage for summer use. The opinions were as follows:

H. W. Wiley. Much more brilliant in color than Roxbury,^a though not perfectly bright. Somewhat unpleasant taste but not spoiled; do not like the flavor so well as that of the preceding sample. Slight flavor of barrel, but not unpleasantly strong. Sample is perfectly sound and sweet, but originally must have been inferior to that of the Roxbury.

After carbonating by running in a rapid stream of carbon dioxide (by means of which dilution of the juice was avoided) Doctor Wiley says: "Flavor much improved. It is now quite as palatable as Roxbury."

W. A. Taylor. I consider this a palatable and refreshing beverage. It has a perceptible cooked taste, but that is not objectionable at a temperature of 15° C. (59° F.). With one part of carbonated water to three parts of juice, the flavor is improved, as the cooked taste of the uncarbonated juice disappears. With one-half carbonated water and one-half apple juice, the fruit flavor fades away.

J. A. Le Clerc. A peculiar flavor, but can not detect any cooked taste. On the whole, it is a very good beverage. There is no alcohol, no perceptible acidity. I think the carbonating improves it and takes away the peculiar taste, the beverage still retaining enough of the apple flavor to make it acceptable; especially is this so with one part of carbonated water mixed with three parts of the cider.

It appears that, although the original juice used for this experiment was not of high quality, when sterilized, cooled, and carbonated it became a palatable and refreshing beverage.

IN CANS.

Experiments in the canning of apple juice during the season of 1906 consisted mainly in the determination of the proper conditions of processing, while during the past season the experiments have been chiefly devoted to investigations as to the quality of sterilized apple juice from different varieties of apples, and the maintenance of quality during storage in cans.

CONDITIONS OF PROCESSING.

A sterilizing process which was found in 1906 to be satisfactory consisted in heating the sealed cans in a water bath to 65° C. (149° F.). This requires from thirty to thirty-five minutes, the water in the bath being kept in constant agitation. The cans were then removed and allowed to cool. The flavor was but little affected by this treatment,

^aA sample of canned Roxbury apple juice was tasted by the committee on the same date (see page 13).

STERILIZATION OF APPLE JUICE.

a very slight cooked taste being apparent. During the past season this treatment has not been found sufficient in all cases (see page 14), and the exact time of heating can not be considered as settled. The process just outlined should be made slightly more severe, either by increasing the temperature or by lengthening the time, or both. In no case, however, should the temperature exceed 70° C. (158° F.).

QUALITY OF JUICE OBTAINED FROM DIFFERENT VARIETIES OF APPLES.

The varieties employed in the season of 1907 were selected by William A. Taylor, pomologist in charge of field investigations, U. S. Department of Agriculture, with a view to securing as wide a range of quality as practicable. Varieties of known high quality were chosen as well as inferior apples; some were high in acid, yielding a rich juice, some contained only moderate amounts of acid, and one variety of sweet apples was employed. The fruit was purchased in lots of 6 barrels each, with the exception of one variety, the Kentucky Red crab, of which it was possible to secure only 3 barrels, and was held in common storage until fully ripe. They were then ground and pressed by a local cider maker, all decayed portions being removed before grinding. The fresh juice was first run through a separator to remove the bulk of the sediment, then canned, and sterilized by the method previously described.

When cooled, the juices were tasted by the committee of three experts before mentioned (page 10), who contrasted the sterilized product with the fresh apple juice. The varieties, locality where the apples were grown, and notes as to quality of juice after sterilizing are given in the following table, the notes being gathered from the opinions of the committee.

TABLE I.—*Organoleptic tests of sterilized juice from different varieties of apples.*

Variety.	Source.	Quality of sterilized juice.
Yellow Newtown (syn. <i>Abemarle Pippin</i>).	Waynesboro, Va.....	Juice very palatable; distinguished from the fresh only by the slight cooked taste and a little bleaching or lightening of the color.
Ralls (syn. <i>Ralls Genet</i>).	Waynesboro, Va.....	Very sweet; rather inspid; would probably blend well with some other juice richer in acid.
Ben Davis.....	Waynesboro, Va.....	Quite unpalatable; lacking in distinctive apple flavor.
Winesap.....	Waynesboro, Va.....	Very palatable; the fruity flavor somewhat impaired by sterilizing; slight bleaching noticeable; very little cooked taste.
Tolman (syn. <i>Tolman Sweet</i>).	Halls Corners, N. Y..	A very dark colored, thick juice; very slight cooked flavor and slight bleaching; very sweet and inspid.
Northern Spy.....	Halls Corners, N. Y..	Very fine in flavor; a fine rich juice, showing slight bleaching, and hardly detectable cooked flavor.
Baldwin.....	Halls Corners, N. Y..	High in quality, very palatable; slightly bleached and with slight cooked flavor.
Roxbury (syn. <i>Roxbury Russel</i>).	Halls Corners, N. Y..	A heavy, rich juice, very palatable; slightly bleached and with very slight cooked flavor.
Shockley.....	Waynesboro, Va.....	Inferior in quality, but superior to Ben Davis; lacking in apple flavor and lacking in acid.
Gilpin.....	Waynesboro, Va.....	Rather inspid, lacks character; a very palatable blend was produced by mixing with Roxbury.
Kentucky Red (syn. <i>Kentucky Crab</i> , possibly).	Mitchell, Ind.....	Very light in color, almost water white; of delicious flavor, rather high in acid. Too light in color and probably too acid for general sale, but blends well with juices which are less rich in acid.

It is clearly shown that sterilized juices of high quality can be produced when first-class fresh juices are used. These tests show that the color is bleached somewhat, and a slight cooked taste is noticed after sterilizing. The general quality of the juice is, however, practically unaffected. The cooked or "boiled cider" taste in many cases was noticeable only when the unheated juice was tasted at the same time. To the writer the change in flavor resulting from sterilizing seems to be due to a slight but distinct loss in fruitiness, rather than to the formation of other flavors. The analyses of the uncooked juices are given in Table II.

TABLE II.—*Composition of unfermented apple juice, 1907.*

Variety.	Date of analysis.	Specific gravity.	Solids, ^a	Acid as malic.	Invert sugar.		Sucrose.
					Reducing sugar.	Total.	
Yellow Newtown (syn. <i>Albemarle Pippin</i>).....	1907. Dec. 17	1.0504	<i>Per cent.</i> 12.35	<i>Per cent.</i> 0.53	<i>Per cent.</i> 9.15	<i>Per cent.</i> 11.58	<i>Per cent.</i> 2.31
Ralls (syn. <i>Ralls Genet</i>).....	19 1908. Jan. 7	1.0564	12.82	.46	11.63	12.14	.48
Ben Davis.....	10	1.0492	12.05	.48	7.86	10.05	2.08
Winesap.....	10	1.0475	11.64	.46	9.06	10.02	.91
Tolman (syn. <i>Tolman Sweet</i>)..	10	1.0638	15.63	.13	9.92	13.95	3.83
Northern Spy.....	11	1.0608	14.90	.61	8.52	12.82	4.09
Baldwin.....	15	1.0584	14.31	.63	7.33	12.22	4.65
Roxbury (syn. <i>Roxbury Russet</i>).....	16	1.0688	16.86	.70	7.46	13.81	6.03
Shockley.....	17	1.0457	11.20	.29	8.70	10.01	1.25
Gilpin.....	24	1.0547	13.41	.38	10.22	11.50	1.22
Kentucky Red.....	24	1.0608	14.90	.72	8.58	12.66	3.88

^a Calculated from the specific gravity, using the formula $S=245(s-1)$; see Browne, J. Amer. Chem. Soc., 1901, 23: 875.

The most palatable juices, Roxbury, Northern Spy, Kentucky Red, and Baldwin, contained about 12 per cent of total sugars, being quite rich in sucrose, and over 0.6 per cent of acid expressed as malic. A rich, rather acid juice thus appears to be most desirable for use in sterilizing. Besides the sugar and acid, the juice should possess a distinctive apple flavor, as was shown in the case of the Ben Davis juice, which, though quite rich, was far from being palatable.

ORGANOLEPTIC TESTS OF CANNED JUICE.

The canned processed juice was tested at intervals by the same group of experts whose opinions have been previously quoted. No deterioration in flavor was noted except in the cases in which the juices were not sterile (p. 14). Besides a slight bleaching effect observed in the juice from the plain cans as compared with juice held in "coated" cans, there was no difference detectable by the judges after nearly six months.

The palatability as a summer beverage of sterilized apple juice kept in tin containers was tested on May 29, 1908. Similar tests on

the juice from the kegs have already been reported (page 10). The comments on the canned juice of Roxbury, both uncarbonated and carbonated, were as follows:

H. W. Wiley.

Roxbury, uncarbonated: Somewhat turbid, sweet, and very palatable.

Roxbury, with addition of about one-fourth volume of carbonated water: Sweet and palatable but not so good as that carbonated before canning.

Roxbury, carbonated before canning: Somewhat turbid. Very agreeable and pleasant tasting; fine beverage, better than either of the other samples.

W. A. Taylor.

Roxbury, uncarbonated: A rich, heavy, satisfying juice with perceptible cooked taste and distinctive russet apple flavor.

Roxbury, with addition of about one-fourth volume of carbonated water: Distinctly better than the noncarbonated juice, being improved by the dilution as well as by the bite due to the carbonation. A very satisfying hot-weather beverage.

Roxbury, carbonated before canning: This is about like that carbonated by the addition of soda water, except that it needs dilution, being a little too rich and heavy.

Roxbury, carbonated before canning with the addition of carbonated water: Adding about one-fourth volume of carbonated water makes it practically like the uncarbonated sample when treated with soda water.

J. A. Le Clerc.

Roxbury, uncarbonated: Very sweet, and pleasant flavor. Free from alcohol and gas; pleasant aroma; no boiled-cider taste.

Roxbury, with the addition of carbonated water: When carbonated in the proportion of 1 part of carbonated water to 3 or 4 of cider, a marked improvement is observed. The drink is just sweet enough, and of a pleasant aroma, the gas of the carbonated water giving it the necessary life; no boiled taste.

Roxbury, carbonated before canning: Very similar to the uncarbonated, but it seems to have a little more life due to the carbonating.

Roxbury, carbonated before canning, with the addition of soda water: Very similar to the uncarbonated juice when treated with soda water under similar conditions.

From these observations it may be concluded that, although the fruit flavor is slightly diminished by sterilizing, the juice has evidently retained much of the characteristic apple aroma and flavor, and when carbonated resembles closely apple cider in the early stages of fermentation.

ACTION OF THE JUICE ON THE TIN OF THE CAN.

Apple juice quickly acts on the walls of the can, bringing out the crystalline structure of the tin. Tests showed, however, that but little tin is actually dissolved during the first few months after canning. The art of can making is now so far advanced that it is possible to exclude practically all metals except tin from contact with canned goods. Several kinds of cans are now on the market, at slightly advanced prices, whose covers are sealed on by the seaming process without the use of solder or acid, and the joint at the sides of the cans

is so made that no solder comes in contact with the interior. Some makers have gone a step farther and provide cans covered inside with a lacquer in order to protect the goods from contamination with tin, this being desired by the manufacturers not only for hygienic reasons but because tin has a deleterious effect on the color of many canned goods.

Two kinds of cans were used as containers for the several varieties of apple juice in this experiment. Both were of the type which practically excludes all metals except tin from contact with the juice. In the case of those designated in Table III as "plain" cans, the juice was exposed to the action of the tin; those designated as "coated" were covered on the inside with a lacquer. The amounts of tin found in various samples of juice and the time the sample had been in the can are given in Table III. These results indicate that while the lacquer was not a perfect protection it materially lessened the amount of tin dissolved, the decrease being nearly 50 per cent.

TABLE III.—*Tin found in canned apple juices.*

Varieties.	Date of analysis.	Time in can.	Kind of can.	Tin (SnO ₂) found.
	1907.	Days.		Gm. per 100 cc.
Yellow Newtown (syn. <i>Albemarle Pippin</i>)	June 13	179	{ Plain.....	0.0080
			{ Coated.....	.0052
Northern Spy	do ..	154	{ Plain.....	.0058
			{ Coated.....	.0026
Roxbury	June 20	156	{ Plain.....	.0061
			{ Coated.....	.0033
Kentucky Red	do ..	148	{ Coated.....	.0059
Mixed varieties	do ..	627	{ Plain.....	.0156

SPOILAGE.

It has been stated (page 11) that the conditions of processing were not absolutely established, since some varieties spoiled in the cans, whereas others, sterilized under the same conditions, remained perfectly sound. The facts observed are as follows: The cans of Tolman some weeks after processing began to swell, and on opening there was a considerable evolution of gas. A butyric acid odor was present, and the juice had become ropy. The cans of the Shockley variety began to swell, some weeks after canning, but on opening showed no ropiness or bad flavor. The Ralls became ropy very slowly, but the flavor did not change materially, and there was no evolution of gas. The Ben Davis juice also became ropy, but no further evidence of fermentation was apparent, and the Gilpin juice showed the same phenomenon. The canning was done in a room which was used at times by others for experiments with dairy products, and it is quite possible that the juice was exposed to contamination not usual in ordinary work. Still, the results would indicate

that sterilization should be effected either by bringing the juice to a higher temperature than 65° C. or by heating for a longer time than thirty-five minutes. It will be noted that the three juices which are low in acid spoiled, namely, the Tolman, the Shockley, and the Gilpin, as well as those containing moderate amounts, as, for example, the Ben Davis and Ralls, plainly indicating the influence of acid in assisting sterilization.

IN GLASS.

In 1906 an extended series of experiments was conducted to determine the best treatment for sterilizing in bottles. The results showed that heating for one hour at 149° F. (65° C.) in a water bath gave good results, and that heating one-half hour at 158° F. (70° C.) was also a satisfactory process, allowing in each case a half hour for the contents of the bottles to attain the bath temperature. The products could be processed for as long as one hour at 158° F. without any marked deterioration, allowing a half hour for preliminary heating, thus making the total time in the water bath one and one-half hours. A very important consideration in the case of bottled apple juice is the removal of the sediment. The milk separator (see page 16) will remove the greater part of the sediment when operating on freshly expressed juice. It does not, however, remove all, so that a brilliant juice is not obtained when clarified in this way. The product is still slightly turbid and gradually deposits a sediment which much impairs the appearance of the cider. Further experiments on sterilizing in glass have been deferred, chiefly because it is felt that there is less need of investigation in this direction than along the line of preparing sterilized apple juice in wood and tin containers.

CLARIFICATION TESTS.

METHODS EMPLOYED.

Freshly expressed apple juice normally contains considerable quantities of insoluble matter. This is true of all apple juices which have been used except Kentucky Red, which was almost free from such material. This insoluble material consists largely of albuminous matter, starch grains, and yeast cells, together with some dirt particles, all of which settles on the bottom of the container, forming a thick, brownish layer. As has been stated, the simplest way of removing the greater part of this material is by the use of the milk separator, as was demonstrated in the experimental work of 1906. This method, however, can only be successfully practiced with absolutely fresh juice.

In the experiments of 1907, owing to the local conditions at the mill where the apples were pressed, it was necessary to grind at night,

and press on the following morning. The experiments on the clarification of the juice were not entirely successful, however, as the albuminous matter was so finely divided by the incipient fermentation that only partial clarification was possible. Large quantities of sediment were, nevertheless, removed by passing the juice through the separator, but the clarification was not so complete as that secured in 1906 when perfectly fresh juice was used. A handpower cream separator of the disk type was employed at that time, which collected the suspended matter in the juice in the bowl of the separator, while the clean juice ran out through the milk and cream screws. After being run through the machine, the heavier particles such as starch grains, or dirt particles, together with some of the albuminous matter, were found tightly packed in the lower part of the tubular shaft in the bowl of the machine, while a heavy layer of albuminous material collected on the inner side of the bowl and a lighter layer on the inner side of the bowl cover. The disks remained free from sediment. When the space between the disks and the sides of the bowl is quite filled with sediment, the flow from the milk screw ceases, and the machine should be cleaned. The juice from the milk screw is invariably considerably clearer than that from the cream screw. The reason for this is not apparent; the fact, however, was always observed. The juice from the cream screw is in turn much clearer than the untreated juice.

RESULTS OBTAINED.

An extended series of tests in 1906 established the following facts with regard to the method of clarifying by passing through a separator, using unfermented juice, and a machine of the size indicated:^a

First. The amount which may be run through the machine before it is necessary to stop and clean the bowl is from 25 to 40 gallons, depending on the quantity of sediment present in the juice.

Second. The rate at which the juice passes through the machine is about 45 gallons per hour, when a delivery tube of 450 pounds per hour (for milk) is employed. On fitting the separator with a delivery tube of 750 pounds' capacity per hour, less perfect clarification was effected than when the smaller delivery tube was used.

Third. But very little increase in the degree of clarification was secured when juice heated to from 140° to 158° F. (60° to 70° C.) was run through.

Fourth. When heated juice was allowed to stand overnight to cool and settle before passing through the separator, the supernatant juice contained much less sediment than the original juice and two to three times as much could be passed through the machine before cleaning became necessary as when unsedimented juice was used.

Fifth. Two separations are necessary when working with a separator of the size employed. The first treatment removes the bulk of the sediment, and the second takes out nearly all of the remainder.

Sixth. Running the juice more than twice through the separator improves the character of the product but little, as only very small amounts of the remaining suspended matter are removed.

^a Yearbook of the U. S. Department of Agriculture, 1906, p. 241.

Seventh. The best conditions, as worked out by experiment, for clarifying apple juice are as follows, working with a hand machine with a capacity for milk of 450 pounds per hour.

(a) The juice must be freshly expressed and, to be of high quality, should be prepared from sound, well-ripened fall or winter apples of suitable varieties.

(b) It should be received in a clean barrel or cask, which must not contain any fermentation residues. This point is very important, as experience has shown that the very fine deposit formed in fermenting juice can not be successfully removed by the separator, and this deposit is difficult to clean from the sides and bottoms of fermentation casks.^a

(c) In passing the juice through the separator, the necessary precautions as to oiling and starting the machine must be used, and the crank should be run at the rate of 45 turns per minute. Twenty-five to forty gallons of fresh juice can be run through before the capacity of the bowl for sediment is reached. The juice which comes through the milk screw should be collected separately.

(d) As soon as the milk screw becomes clogged the machine should be stopped and the bowl cleaned.

(e) The juice collected from the milk screw should be passed through again and that coming from the milk screw collected as before.

The clarification of 25 gallons of juice (using one machine of the capacity indicated and a juice containing sediment in such quantity that the run would fill the space between the disks and the sides of the bowl with sediment) requires about one hour and a quarter, the juice passing through the bowl twice.

These details are given in order to assist others who may wish to clarify in this way. Clarification by means of centrifugal force could probably be greatly improved if a machine designed primarily for the purpose were used.

CARBONATING.

Experiments in carbonating apple juice were carried on during 1906 to determine whether or not the palatability of the sterilized juice could be increased and the slight cooked taste be disguised.

METHODS EMPLOYED.

The following methods were tried in the work of 1906:

The juice was carbonated under slight pressure and then heated in bottles or cans. In the simple experiments conducted in connection with this work, the carbon dioxid (carbonic-acid gas) was secured from a firm dealing in soda-water supplies. It was obtained in liquid form in a steel cylinder furnished with a reduction valve and a gauge and delivery tube, so as to deliver at a pressure up to 30 pounds.

After clarifying, the juice was carbonated by pouring about 12 gallons of it into a clean keg and running in the gas up to a pressure of 15 pounds. The keg was provided with a thick pine bung, through the middle of which was bored a half-inch hole, which received the rubber delivery tube from the cylinder of compressed gas. The bung was soaked in water for a few minutes before use, so that it could be driven in to make a tight joint, and was so fitted that it projected beyond the surface of the keg and could be readily loosened when carbonation was finished. Carbon dioxid was ad-

^a This point is confirmed in the experiments of 1907 (see p. 15).

mitted before driving the bung in air-tight in order to expel the air which fills the space in the keg not occupied by the juice. The bung was then driven in by tapping with a hammer and more gas admitted. The keg was vigorously rocked so as to thoroughly agitate the juice and thereby accelerate the absorption of the gas.

The gauge was watched, the pressure not being allowed to go beyond 15 pounds per square inch. The juice used in the carbonating work was quite cool, ranging from 48° to 68° F. (9° to 20° C.) in the different experiments. From fifteen minutes to one-half hour was required to carbonate 12 gallons of juice. The stream of gas was then stopped, the bung cautiously loosened, the contents of the keg poured out, and the juice bottled or canned.

The gas remains for some time in the juice when under atmospheric pressure and only gradually diminishes in quantity, so that great haste in sealing the containers is not necessary. If the carbonated juice is to be sterilized in cans, they must be heated in stout frames to prevent the distortion of the can while hot and consequent bursting. The finished canned product bulges the ends of the cans to some extent, but not enough to cause permanent bending. The juice must not be too highly charged with the gas nor removed from the frames while still hot, or such bending, with consequent weakening of the soldered joints and bursting of the can, may occur.

Several varieties of apple juice were carbonated and then canned by this method during the past season, and it was found that the presence of the gas added an agreeable sparkle to the juice, at the same time, however, introducing a flavor foreign to fresh unfermented apple juice. If sterilized apple juice were sold at a soda fountain, it would be simple to add carbonated water, or cool the juice and run in carbonic-acid gas under pressure. In this connection it should be mentioned that apple juice acts rapidly on metals, particularly on galvanized iron, and if the juice is carbonated in tanks care should be taken that they are lined inside with tin rather than with any other common metal and that the juice is not kept in metallic containers.

USE OF CARBON DIOXID TO PREVENT MOLD.

It has been found that when sterilized apple juice is exposed to the air the organisms which usually develop are not those which produce the alcoholic fermentation but are molds which grow on the surface of the juice, giving rise to disagreeable flavors and soon making the juice undrinkable. Since the molds are usually aerobic organisms, it was thought possible to retard their development in most cases by maintaining an atmosphere of carbonic-acid gas over the juice. The following experiment was tried:

In June, 1908, about a gallon of sterile Northern Spy apple juice was placed in two large bottles, each bottle being about half full. The juice was poured from one bottle into the other, taking no precautions to protect it from contact with the organisms of the atmosphere.

One bottle was then stoppered and into the juice in the other bottle a rapid current of carbon dioxide was passed for about ten minutes, in this way partly saturating the juice with carbon dioxide

and displacing the air above the juice by the gas. This bottle was also tightly stoppered and the two were kept side by side in the laboratory. The following observations were made:

After three days a slight growth was observed on the surface of the juice which was untreated with carbon dioxid; no growth was apparent on the juice treated with gas.

On the following day thirteen colonies, several of which showed greenish groups of spores, were found on the untreated apple juice; none was found on the surface of the other. On June 8, three days later, there was a much greater development of spores and mycelia on the surface of the untreated apple juice, which had a flavor suggesting rotten apples. On the surface of the other juice there were found several filmy growths, but no development of organisms giving a disagreeable flavor. On removing the stopper there was a slight gas evolution and the liquid evolved carbon dioxid slowly, indicating that alcoholic fermentation was starting. No unpleasant flavor was apparent. A repetition of the experiment gave similar results, namely, the suppression of mold growths. It would probably be possible, in case the product is sold at soda fountains from small kegs, to saturate the juice and fill the air space above it with carbonic-acid gas, thus suppressing the development of the mold for a limited time.

Another method of eliminating mold on the surface of the liquid, or preventing fermentation, would be to open the package under sterile conditions and insert a sterile faucet such as has been described by Dodson ^a of the Louisiana experiment station. This spigot is so arranged as to allow the entrance of air during the outflow of the liquid, the incoming air being filtered through cotton. If such a faucet is used for apple juice, however, it must be made of porcelain or wood.

EFFECT OF BENZOATE OF SODA AS A PRESERVATIVE.

Apple juice at present is largely sold in bulk, using a small amount of benzoate of soda to retard fermentation, one-tenth of 1 per cent being tolerated by regulation in the United States. An experiment was carried on to determine the effect of sodium benzoate when added in varying amounts to apple juice, with a view to finding out how long such juice would keep and what quality of juice resulted after standing for different lengths of time. For this purpose five 10-gallon kegs which contained sterile apple juice were opened and a culture of a pure yeast, supplied by W. B. Alwood, was added to each keg. Varying amounts of benzoate of soda were added and the kegs were kept nearly full and closed by tightly fitting cotton plugs.

^a Louisiana Agr. Exper. Stat., 1903, second series, Bul. No. 75, p. 256.

The cotton became wet with juice, however, and soured; the juice in the kegs in this way became infected with acid-forming organisms. Analyses were then made at intervals with the results shown in Table IV.

TABLE IV.—*Changes in composition during storage of apple juice containing various amounts of benzoate of soda.*

Description of sample.	Date of analysis.	Time of storage.	Specific gravity.	Solids.	Total acid as acetic.	Volatile acid as acetic.
	1907. Nov. 16	Days.		Per cent.	Per cent.	Per cent.
Original unfermented juice.....	Nov. 16	-----	1.0499	12.22	a 0.35	-----
	1908.					
Fermented juice, no benzoate of soda....	Jan. 28	73	.9974	1.41	.71	0.49
	Mar. 18	123	1.0005	1.30	1.79	1.61
	May 26	192	1.0060	1.41	3.77	-----
Fermented juice +0.03 per cent of benzoate of soda.....	Jan. 28	73	1.0060	3.24	.70	.38
	Mar. 18	123	1.0076	3.03	1.53	1.47
	May 26	192	1.0103	2.56	2.99	-----
Fermented juice +0.06 per cent of benzoate of soda.....	Jan. 28	73	1.0184	5.66	1.15	.53
	Mar. 18	123	1.0135	3.94	2.08	1.81
	May 26	192	1.0215	3.91	4.84	-----
Fermented juice +0.10 per cent of benzoate of soda.....	Jan. 28	73	1.0502	12.48	.90	.39
	Mar. 18	123	1.0452	11.08	1.26	.71
	May 26	192	1.0176	4.73	2.59	-----
Fermented juice +0.15 per cent of benzoate of soda.....	Jan. 28	73	1.0517	12.44	.76	.25
	Mar. 18	123	1.0251	6.94	1.06	.53
	May 26	192	1.0213	5.16	2.77	-----

Description of sample.	Date of analysis.	Fixed acid as malic.	Alcohol.	Invert sugar.		Sucrose.
				Reducing sugar.	Total.	
	1907. Nov. 16	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Original unfermented juice.....	Nov. 16	-----	-----	9.29	10.21	0.87
	1908.					
Fermented juice, no benzoate of soda....	Jan. 28	b 0.25	5.39	.13	.24	.10
	Mar. 18	c. 11	4.17	.11	-----	-----
	May 26	-----	2.03	.21	-----	-----
Fermented juice +0.03 per cent of benzoate of soda.....	Jan. 28	b. 36	4.55	1.59	1.73	.13
	Mar. 18	c. 13	3.75	1.43	-----	-----
	May 26	-----	2.40	1.10	-----	-----
Fermented juice +0.06 per cent of benzoate of soda.....	Jan. 28	b. 69	3.12	3.61	3.73	.11
	Mar. 18	c. 27	2.77	2.04	-----	-----
	May 26	-----	.35	2.02	-----	-----
Fermented juice +0.10 per cent of benzoate of soda.....	Jan. 28	b. 56	.42	9.64	10.13	.47
	Mar. 18	c. 48	.76	8.52	-----	-----
	May 26	-----	2.53	2.40	-----	-----
Fermented juice +0.15 per cent of benzoate of soda.....	Jan. 28	b. 57	.09	9.80	10.16	.34
	Mar. 18	c. 52	2.56	4.76	-----	-----
	May 26	-----	1.70	2.70	-----	-----

a Calculated as malic acid. b Difference between total and volatile acids. c Determined analytically.

It will be noted that the juice which contained no benzoate of soda became practically dry during the first interval of 73 days, containing 1.41 per cent of solids and 0.24 per cent of total sugars as invert. The specific gravity fell to slightly less than 1. There was a formation of 5.39 per cent of alcohol and also formation of acetic acid, while the fixed acid suffered a slight loss. From this time on the usual aceti-

fication ensued, which was not complete on May 26, the time of the last analysis.

The juice which contained 0.03 per cent of benzoate of soda fermented considerably during the first interval, yielding 4.55 per cent of alcohol, a little acetic acid being formed at the same time. The juice, however, was far from being dry, 3.24 per cent of solids, including 1.73 per cent of total sugar, calculated as invert, being present. During the next interval there was a slight gain in total acid calculated as acetic, and a slight loss in alcohol. The sugar also diminished, and after one hundred and ninety-two days there were present 2.56 per cent of solids, 2.99 per cent of acid calculated as acetic, 2.40 per cent of alcohol, and 1.10 per cent of reducing sugar. The addition of 0.03 per cent of benzoate of soda, therefore, retarded the alcoholic fermentation, but permitted the alcohol formed to acetify.

Juice preserved by the addition of 0.06 per cent of benzoate of soda showed a greater retardation of fermentation, containing at all times considerably more solid matter, more sugar, and less alcohol. At the time of the last examination, however, it showed not only much less alcohol, but much more acetic acid than any of the other samples, still containing 3.91 per cent of solids, of which 2.02 per cent were sugars.

The juices containing 0.1 per cent and 0.15 per cent of benzoate of soda, respectively, showed during the first interval of seventy-three days practically no alcoholic fermentation, but increased considerably in content of total acid calculated as acetic. After one hundred and twenty-three days the juice to which 0.1 per cent of benzoate of soda had been added contained 11.08 per cent of solids, 1.26 per cent of acid as acetic, 8.52 per cent of sugar, and 0.76 per cent of alcohol. After one hundred and ninety-two days it had lost a large amount of its solid matter, but only small amounts of acetic acid and alcohol were present.

It was expected that the juice which contained 0.15 per cent of benzoate of soda would show less loss in solids than any of the other juices. This, however, was not the case. The reason for this may be that different organisms developed in the different barrels, and these were affected differently by the presence of the preservative.

Therefore, while benzoate of soda when added in quantities of 0.03 per cent and over retards alcoholic fermentation, eventually both alcoholic and acetic fermentation do develop, and an attempt to preserve apple juice as a beverage for any length of time by the use of benzoate of soda in quantities tolerated by the regulations would result in failure due to the development of acetic fermentation and consequent depreciation in flavor.

The alcoholic fermentation which would naturally take place in the absence of both preservatives and sterilization tends to exclude other

organisms, such as the molds and acetic acid ferments which require the presence of air for their development. The carbon dioxide produced by the action of the yeast on the sugar displaces the air above the juice in the container, and the air originally present in the juice is probably utilized by the yeast in its development so that such juice, if properly handled, yields a sound, fermented apple juice or cider. In the presence of preservatives, however, the yeasts are not permitted to develop and exert their effect of excluding other organisms, some of which will develop and produce bad flavors, rendering the juice unpalatable if not totally unfit for consumption. Sterilization, on the other hand, excludes the yeasts and the other organisms as well, so that the original flavor of the product, aside from a slight change due to heating, is maintained.

SUMMARY.

(1) The experiments described show conclusively that it is possible to sterilize apple juice in wooden containers, the product remaining sound for at least six months under actual observation. The precautions which must be taken to insure this are as follows: First paraffin the containers on the outside, then sterilize, and fill with juices heated to between 149° and 158° F. (65° to 70° C.); seal, taking measures to relieve the vacuum produced by the contraction of the juice on cooling by filtering the air through cotton. Twenty-four 10-gallon kegs successfully stood a severe shipping test, showing no loss due to fermentation of the juice. The juice so prepared was found to be palatable, and acceptable as a summer drink.

(2) It is demonstrated that apple juice can be successfully sterilized in tin containers, using the type of tin can sealed by the mechanical process, excluding all metals from contact with the juice except the tin of the can. Where lacquered cans are used the contamination with tin was reduced about one-half. Apple juices were canned and sterilized by heating in a hot water bath, up to the temperature of 149° F. (65° C.) for a half hour, and then were allowed to cool. These juices possessed only a slight cooked taste due to the heating and retained much of their distinctive apple flavor. It was found that from finely flavored apple juice a first-class sterile product could be made, while a poorly flavored apple juice yielded an inferior product. The process conditions mentioned were not quite thorough enough to sterilize all of the varieties canned. A slight increase in the temperature or time of processing, or both, should be made, the temperature not to exceed 70° C. (158° F.) in any case.

(3) The best treatment for sterilizing in glass was found to consist in heating for one hour at 149° F. or for one-half hour at 158° F. Heating for one hour at 158° did not produce marked deterioration in flavor,

a half hour being allowed in all cases for the juice to obtain the temperature of the water bath.

(4) It was shown that the great bulk of the insoluble material naturally contained in apple juice can be removed by means of a milk separator.

(5) It is possible to carbonate the juice slightly before canning or bottling, thus adding a sparkle to the product. A flavor foreign to fresh apple juice is also added, however, and uncarbonated sterile juice will resemble fresh apple juice more closely. Carbonating by the addition of water charged with carbon dioxid was considered by some to injure the flavor, lessening the characteristic fruit flavor by dilution. In the opinion of others a heavy, rich juice was improved both by the charge of carbon dioxid and by the consequent dilution. Experiments indicated that the danger of contamination by mold growths was lessened by maintaining an atmosphere of carbon dioxid above the surface of the juice after opening.

(6) It is demonstrated that benzoate of soda in quantities varying from 0.03 to 0.15 per cent (0.1 per cent being the maximum temporarily permitted by the food regulations), while it checks the alcoholic fermentation, allows other organisms to develop (notably the acetic acid ferment), whereby the palatability of the product as a beverage is destroyed.

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